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EXPLORING IN AEROSPACE ROCKETRY

18. LAUNCH OPERATIONS

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Advisor, James F. Connors

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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18. LAUNCH OPERATIONS

Maynard I. Weston*

Launching and monitoring the flight of an unmanned scientific probe takes a good deal of money and the dedicated hard work of literally thousands of people. This effort can be clearly seen in the Atlas-Agena Lunar Orbiter B program. Although the vehicle has only a booster and an upper stage and involves fewer people and organizations than the more complicated Apollo launch vehicle, the types of activity needed to launch the Atlas-Agena are the same. The problems of the smaller vehicle illustrate those of the larger. For example, the same general type of documentation that is shown in table 18-1 for the planning of an Atlas-Agena launch is required for all space launches regardless of vehicle size.

This discussion of the Atlas-Agena-Orbiter concentrates on the hardware, organization, testing, and support of a typical launch.

HARDWARE

Spacecraft

The Lunar Orbiter B spacecraft weighs 845 pounds and is covered by an aerodynamic shroud during atmospheric flight. In this configuration, with its solar panels and antennas folded, it is about 5 feet in diameter and almost 6 feet long. When the panels and antenna are unfolded in space, the maximum span increases to almost 19 feet. The spacecraft is carried into a translunar trajectory by a two-stage Atlas-Agena launch vehicle (fig. 18-1).

The main object of the Lunar Orbiter program is to learn as much as possible about the topography of the Moon. This information will be particularly useful during the Apollo manned lunar landings. The Orbiter spacecraft are equipped with cameras to give a detailed picture of the Moon's surface, and each Orbiter in the series travels a different path to photograph a different portion of the Moon.

*Chief, Operations Branch, Agena Project.

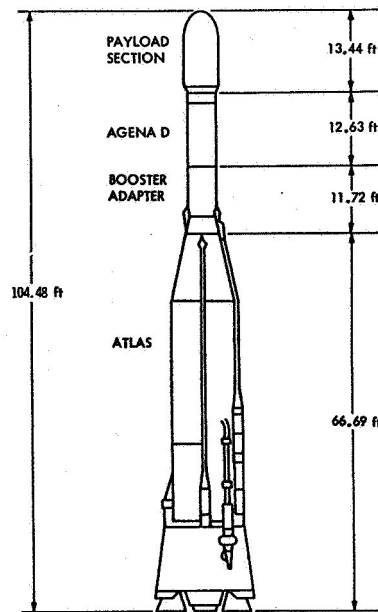


Figure 18-1. - Atlas-Agena launch vehicle.

Atlas Booster

The first stage of the launch vehicle, an Atlas booster (fig. 18-2), is built by General Dynamics/Convair and is about 70 feet long and 10 feet across, although it widens to 16 feet across the flared engine nacelles. The 388 340 pounds of thrust that propels the Atlas is generated by a booster system with two thrust chambers, a sustainer engine, and two vernier engines. All are single-start, fixed-thrust engines and operate on

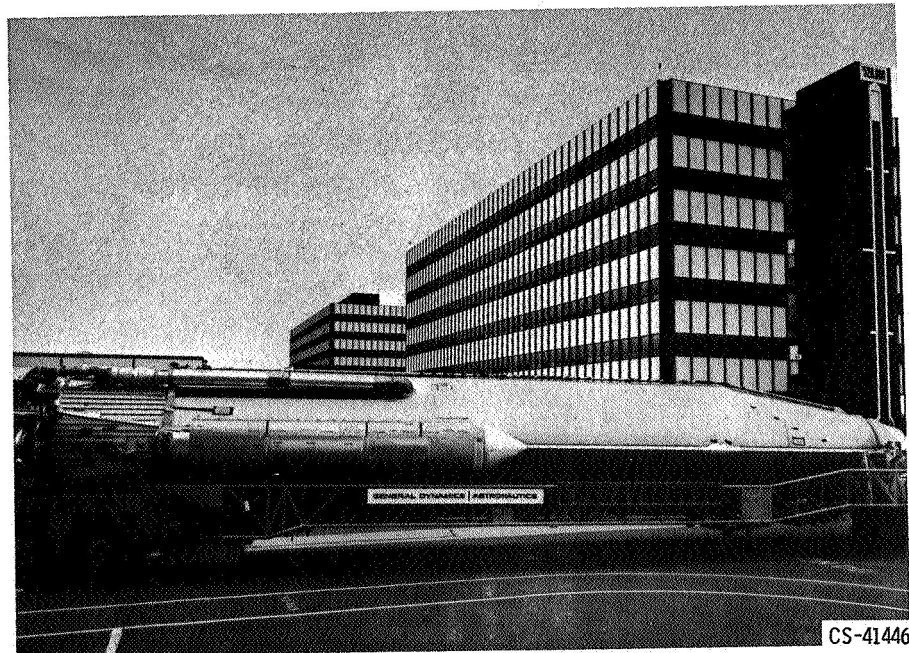


Figure 18-2. - Atlas booster.

liquid oxygen and kerosene. The Atlas is radio controlled by a computer-operated, ground-based system.

Agena Rocket

Lockheed Missiles and Space Company builds the second stage, an Agena rocket. It is about 23 feet long and 5 feet across. The liquid-propellant engine uses unsymmetrical dimethylhydrazine (UDMH) as fuel and inhibited, red, fuming, nitric acid (IRFNA) as oxidizer to generate 16 000 pounds of thrust for 240 seconds. This total thrust time can be divided into two separate burns. The Agena is guided by a preprogrammed autopilot system using horizon sensors and a velocity meter cutoff.

Launching Facilities

The Atlas-Agena-Orbiter is launched from Complex 13 at Cape Kennedy. All necessary facilities for conducting final tests, fueling, countdown, and launch, as well as installations for tracking, photographing, and monitoring significant events during the preparation, countdown, and launch, are available at Complex 13. These facilities and their relation to the remainder of Cape Kennedy are shown in figures 18-3 and 18-4. The launch complex has two major portions, the blockhouse and the test stand, and a variety of lesser supporting installations.

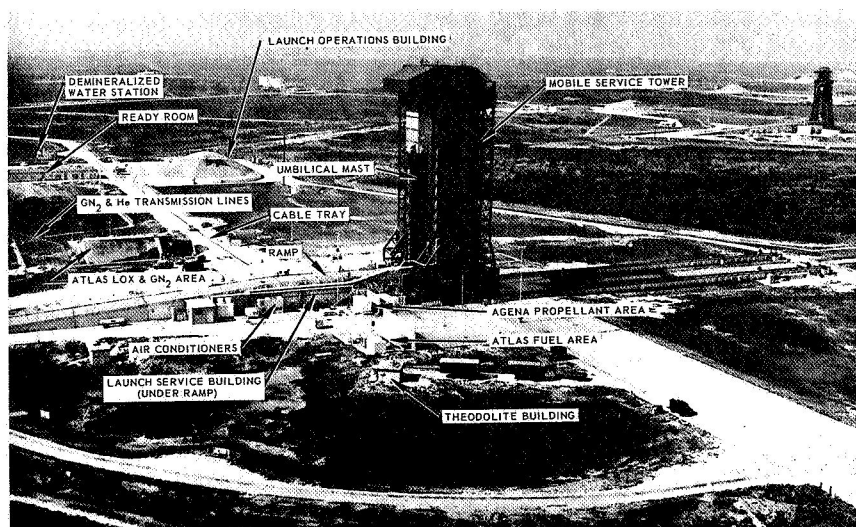


Figure 18-3. - Launch Complex 13 at Cape Kennedy.

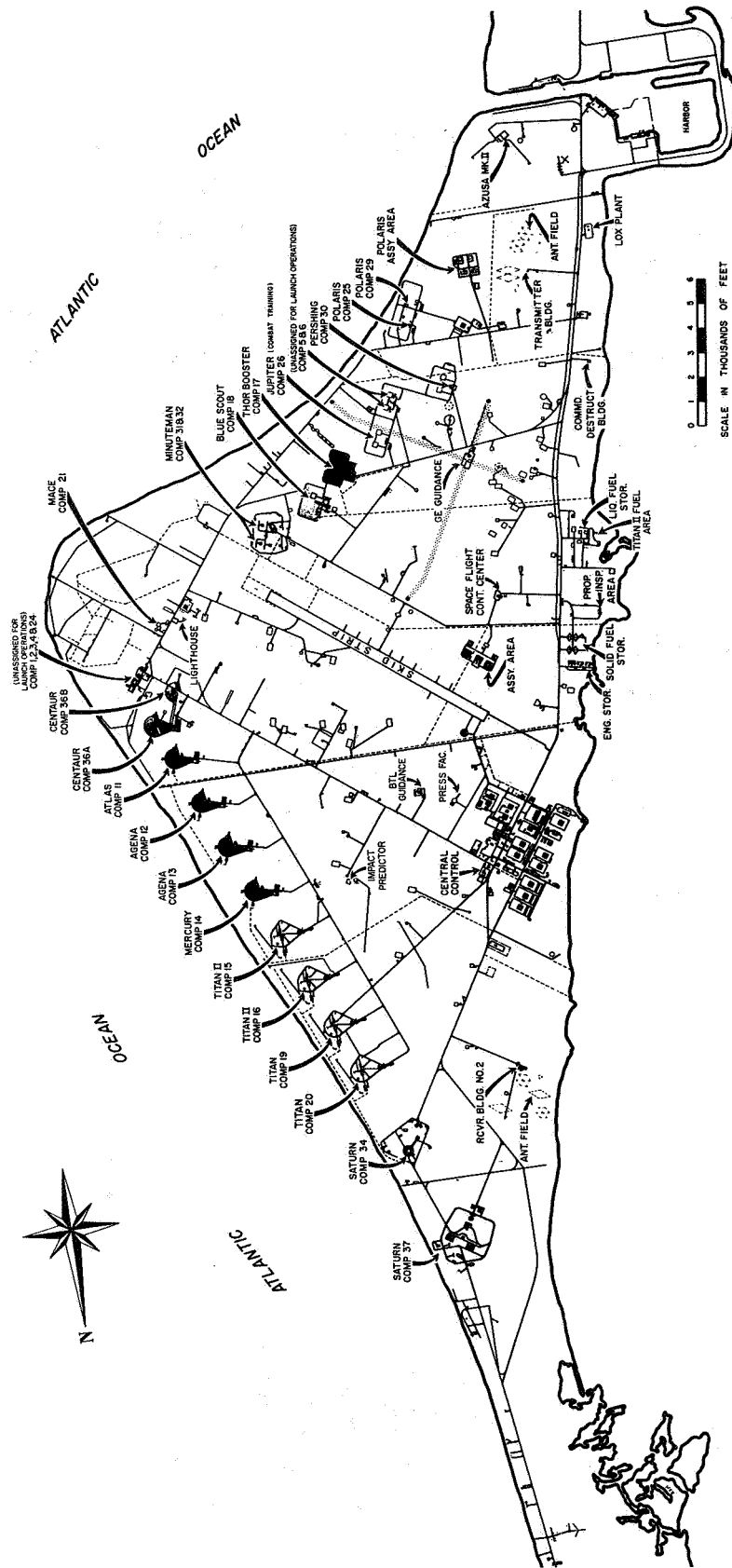


Figure 18-4. - Cape Kennedy facilities.

Blockhouse. - This structure is the control center for the entire launch operation. It is made of concrete, heavily reinforced with steel, has approximately 6400 square feet of floor space, and is about 800 feet from the test stand; a single, vault-type door is its only entrance, and this is sealed during launching. Inside are the consoles and equipment to control and monitor all systems of the launch vehicle, propellant loading and unloading, automatic sequencing, communications, launch pad, closed-circuit television, and land-line recording. The blockhouse is connected to the launch pad and propellant service area by weatherproof wiring tunnels.

Although the blockhouse has the facilities to monitor important spacecraft functions, as well as those of the vehicle, the primary center for this activity is the Deep Space Station at Cape Kennedy.

Test stand. - The major installations which comprise the test-stand area are the launch service building, the launcher mechanism, the service tower (gantry), the umbilical mast and boom, the propellant storage tanks and transfer equipment, various gas storage and loading facilities, general storage areas, and workshops.

The gantry is used for erecting the Atlas, the Agena, and the spacecraft, and for supporting the system during checkout and countdown. A launch mechanism is used for controlling the vehicle during the first moments of launch. The last function is effected by pneumatically operated holddown clamps, which restrain the vehicle until thrust is strong enough to ensure a stable flight.

Near the gantry is the spacecraft checkout van. It contains the facilities to test and monitor the operation of this system.

ORGANIZATION

A single agency is assigned complete responsibility for each NASA mission. Depending on the type of mission, this agency might be the Jet Propulsion Laboratory, the Goddard Space Flight Center, or one of the other NASA institutions. In the case of the Lunar Orbiter program, the operation is directed by the Langley Research Center (LRC), which coordinates the work of several different private, public, and military organizations. The Orbiter involves four major activities: The Lewis Research Center (LeRC) is responsible for the launch vehicle, the Eastern Test Range (ETR, an Air Force activity) for the launch and range support, the Jet Propulsion Laboratory (JPL) for coordinating and integrating tracking and data acquisition systems, and finally Langley's own development of the spacecraft. The overall organization of government and contractor elements responsible for the Lunar Orbiter prelaunch operations is shown in figure 18-5.

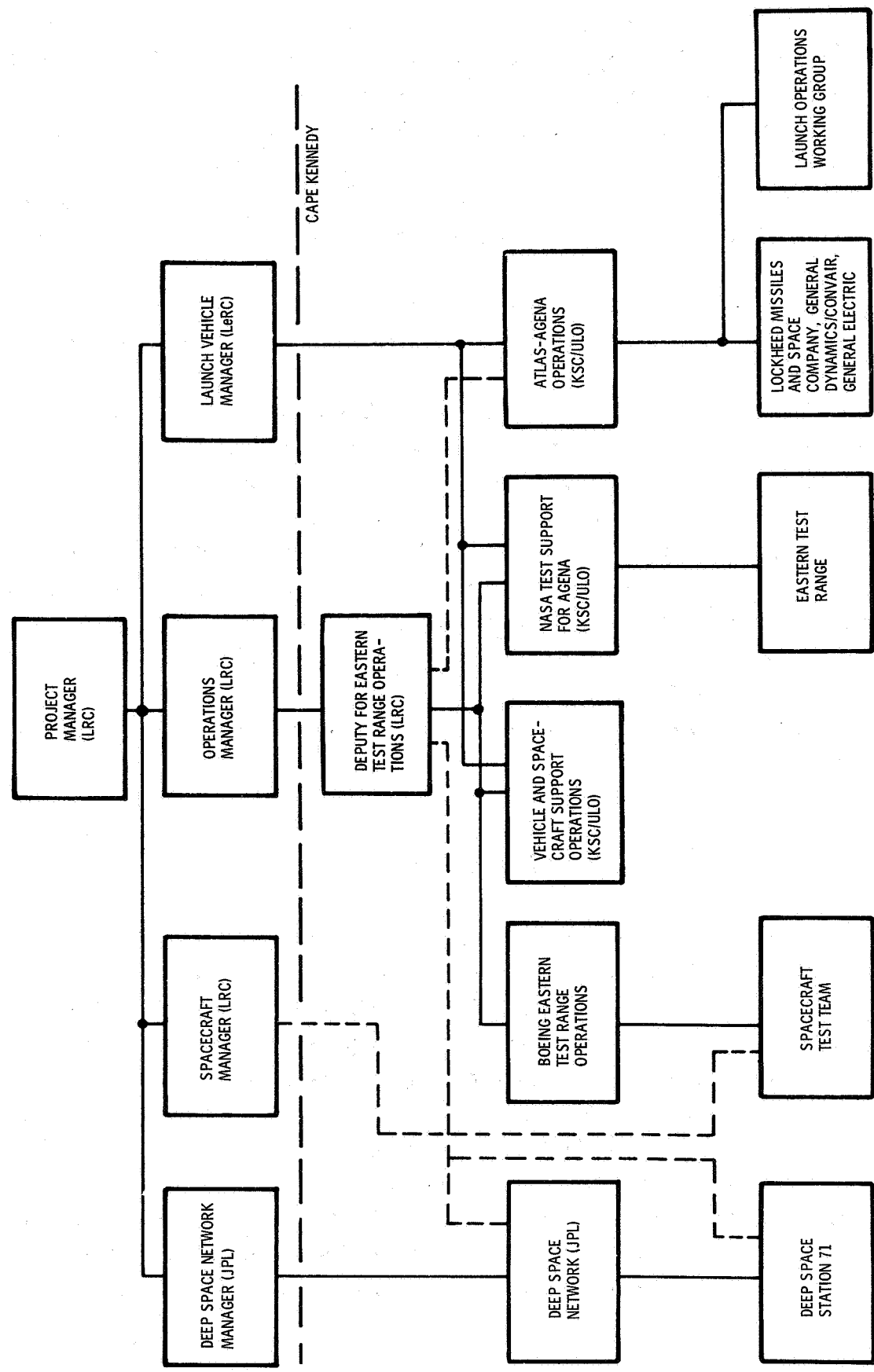


Figure 18-5. - Lunar Orbiter organization for Cape Kennedy prelaunch operations.

Launch Vehicle

Since the Atlas-Agena vehicle has two stages, the Lewis Research Center must coordinate the work of two contractors, General Dynamics/Convair (GD/C) and Lockheed Missiles and Space Company (LMSC). Each of these organizations is responsible for manufacturing, testing, and installing its section on the launch pad - GD/C the Atlas and LMSC the Agena. Lockheed, moreover, is responsible for integrating the two stages.

Spacecraft

Once the two stages are in place, the spacecraft must be installed. This is done by its contractor, The Boeing Company (TBC), under the direction of Langley Research Center.

Launch Facilities

The Eastern Test Range is operated by the Air Force to provide all the necessary supporting staff and installations required to launch and use space missions. The ETR coordinates the Atlas-Agena-Orbiter program with other launching activities, maintains the launching complex, and manages the lesser but important services such as housing, security, safety, and weather.

Tracking and Data

The tracking of the launch and the collection of the data that are the reason for the Orbiter are done by ETR in conjunction with the Deep Space Network, which is under the direction of the Jet Propulsion Laboratory.

PREPARATION AND LAUNCH

Preambly Tests

Before the Atlas-Agena-Orbiter is launched, it must pass through several inspections and tests, both as individual components and as an assembled unit. Even before delivery to Cape Kennedy, each section must have passed a final quality test at the contractor's plant. Upon arrival at the Cape (figs. 18-6 and 18-7), each section is again tested by its contractor and then assembled. Figures 18-8, 18-9, and 18-10 show major assembly steps.

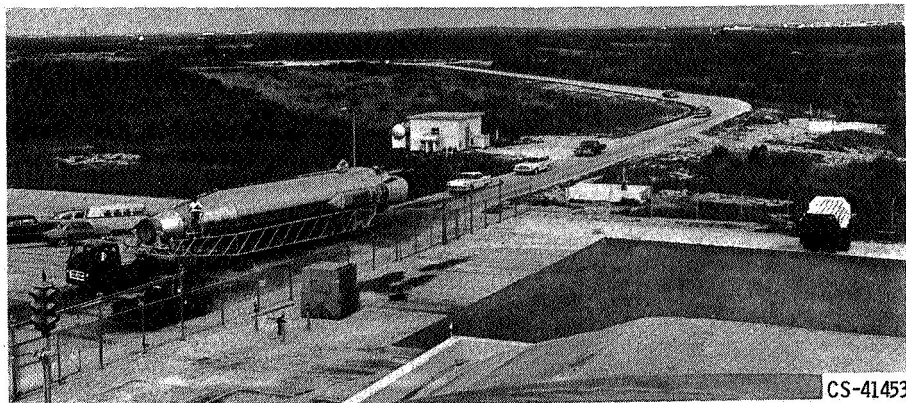


Figure 18-6. - Atlas transport to pad.

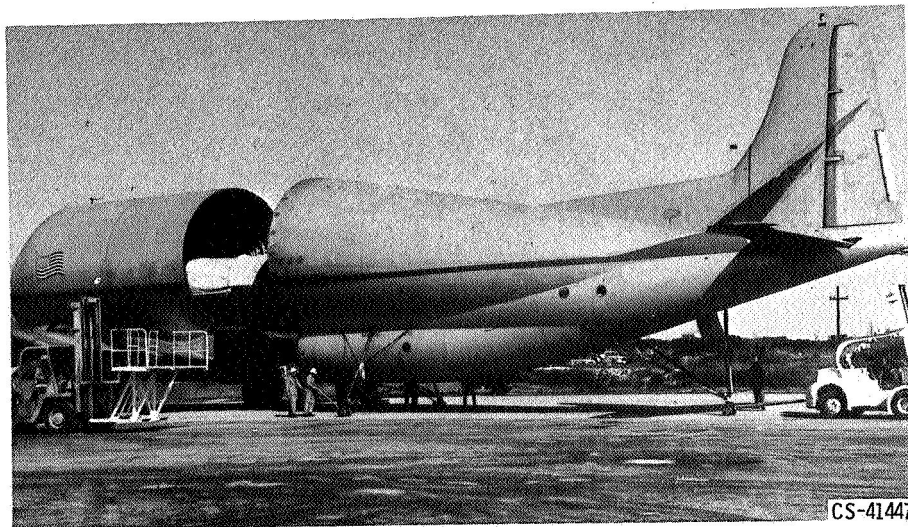


Figure 18-7. - Arrival of Agena stage.

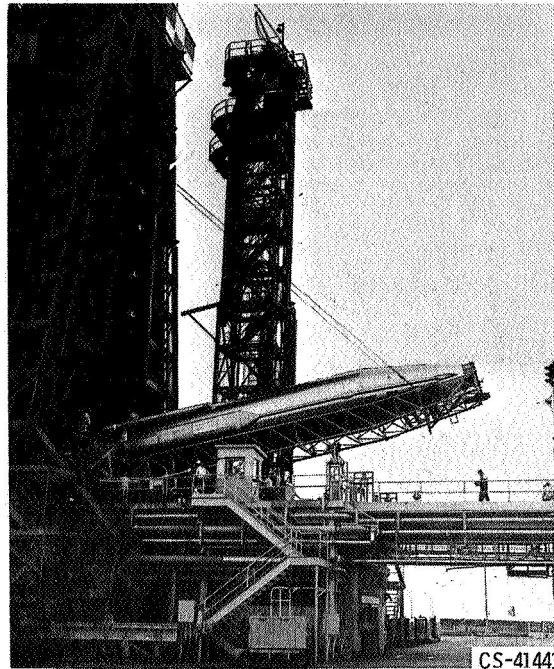


Figure 18-8. - Atlas being erected on pad.

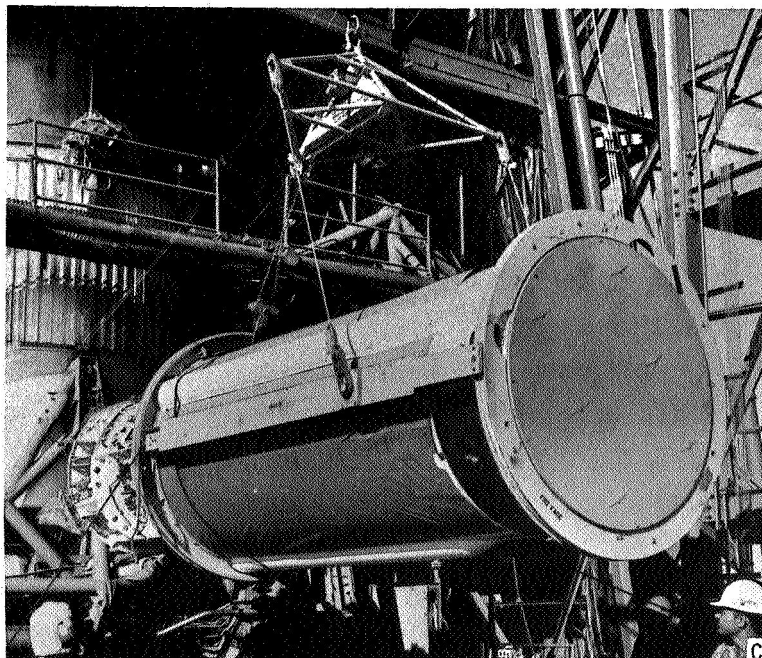


Figure 18-9. - Agena being raised to top of Atlas.

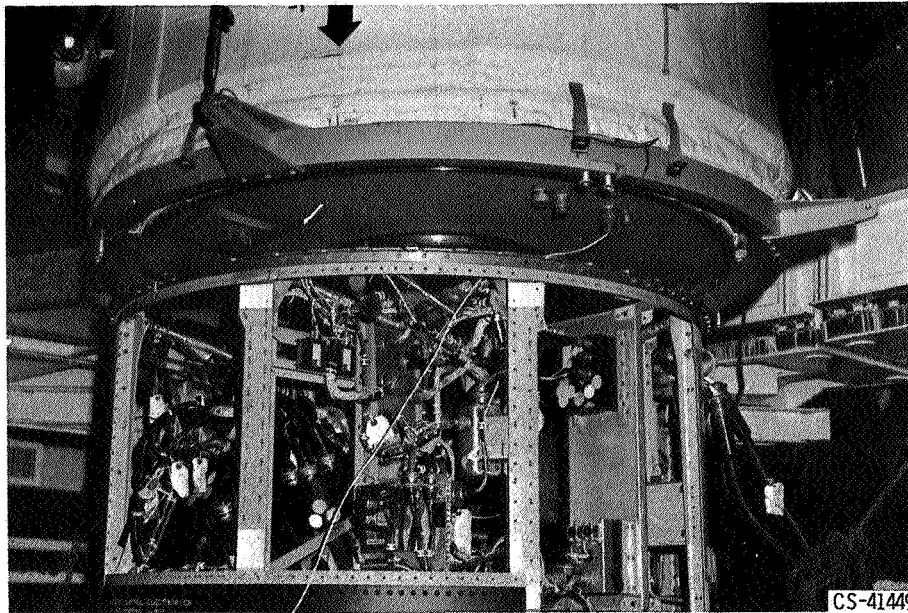


Figure 18-10. - Mating encapsulated Orbiter-B to Agena.

Assembly and Testing

The first stage, the Atlas vehicle, is the first section to be erected on the launch pad. As soon as it is in place, it is tested to ensure that all systems are still functioning properly and will respond only to the correct signals from the blockhouse. In addition, the Atlas fuel tanks are checked to make sure that they will withstand the temperatures and pressures imposed on them without leaking.

After the first stage is in place and has passed all the inspections, the Agena is installed. Testing now is conducted not only on the Agena but also on the electrical and mechanical connections between it, the Atlas, and the ground equipment.

The spacecraft is the last section to be installed on the vehicle. Again, the assembly tests are conducted to establish both the individual and combined reliability.

After it is determined that all systems of the Atlas-Agena-Orbiter and all systems on the ground are operating perfectly, a simulated launch is conducted. This operation gives the final assurance that all systems have been correctly integrated and that all supporting ground facilities are ready for the launch. This full dress rehearsal is as realistic as possible, even including fueling; only the last 19 seconds before the actual firing are omitted.

The prelaunch tests and operations outlined in figure 18-11 take place according to the schedule presented in figure 18-12.

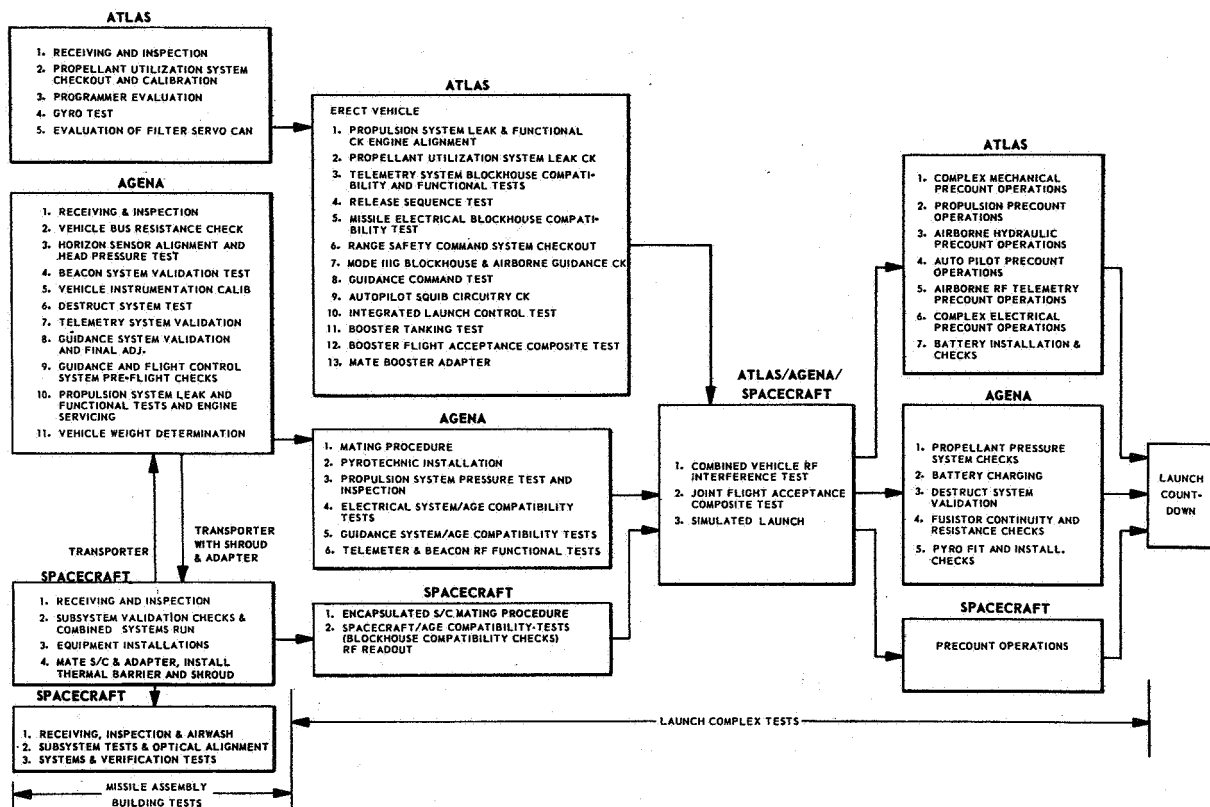


Figure 18-11. - Prelaunch operations flow chart.

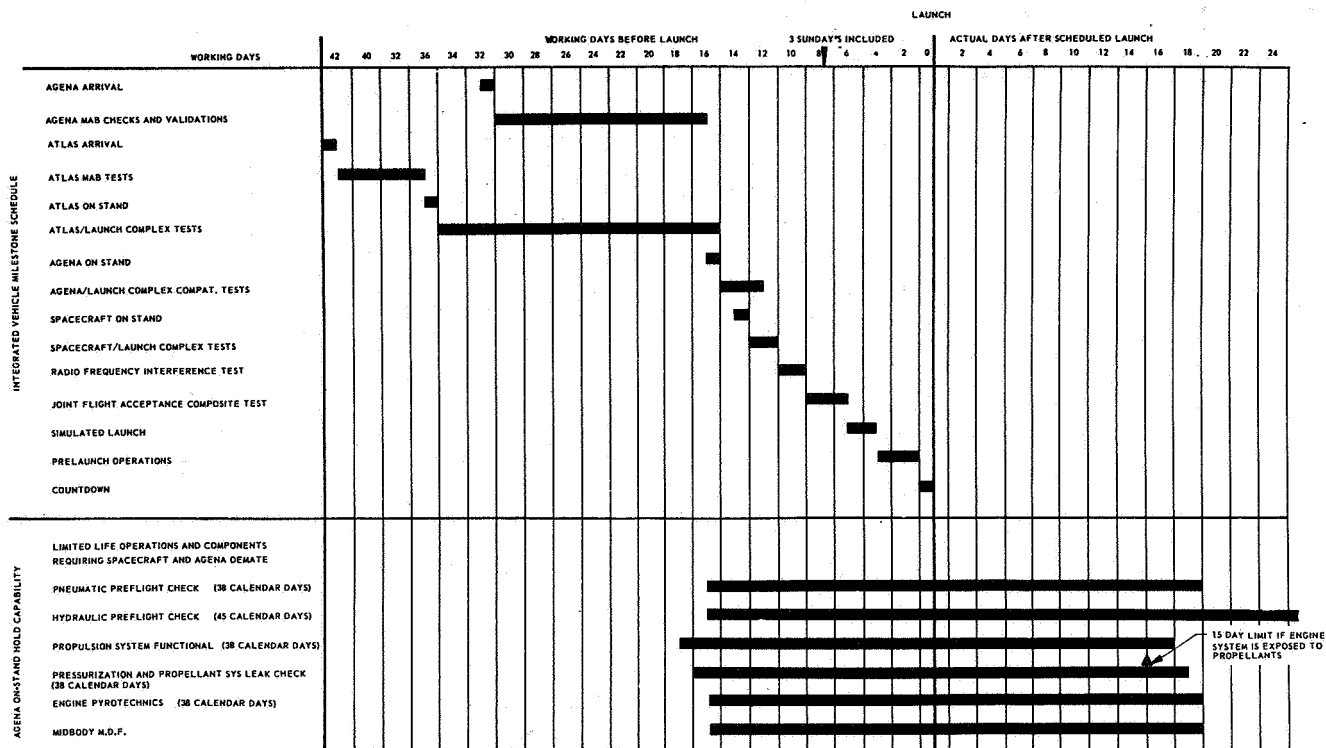


Figure 18-12. - Atlas-Agena-Orbiter integrated-vehicle milestones and Agena on-stand hold capability.

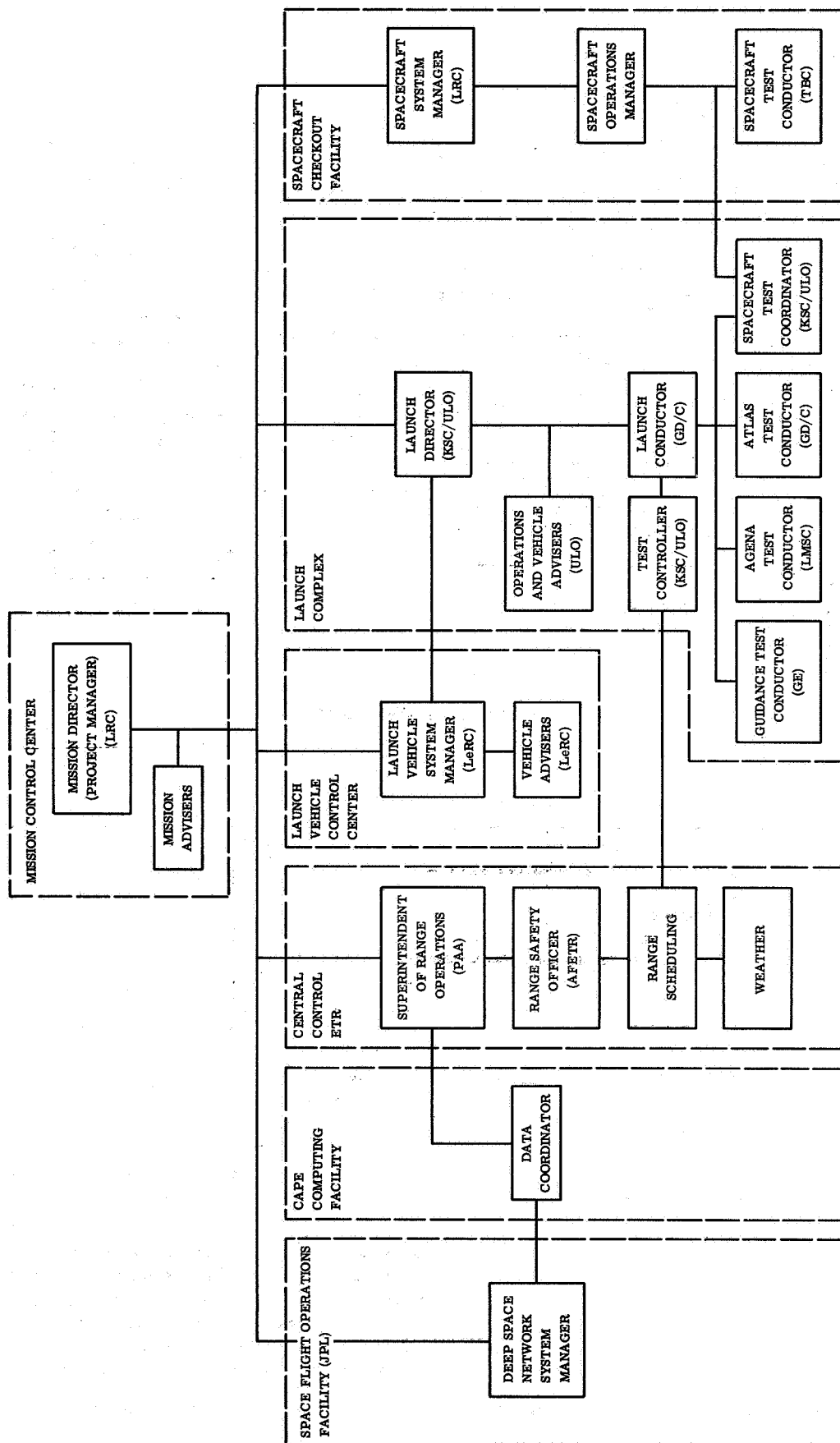


Figure 18-13. - Functional organization of space-flight operations.

Launch

The coordination of all the activities which must take place during a launch is handled by the Unmanned Launch Operation Directorate at the Kennedy Space Center (KSC/ULO). The relation of KSC/ULO to the other activities is shown in figure 18-13.

The operations and tasks that are performed during the countdown preceding the actual launch are carefully timed to ensure that nothing is overlooked and that everything is done in the correct order. Among the many tasks are fueling and checking all command and execution systems of the spacecraft, the vehicle, and the ground facilities. A summary of the countdown procedure is presented in table 18-II.

Although the launch is the most spectacular moment of the Atlas-Agena-Orbiter mission, it is probably the least demanding technically. Its success depends entirely on the thoroughness and accuracy of all the testing inspections and verifications that have gone on before. Design, manufacturing, and assembly play an important part as well. The launch is a conclusion, not a process.

WORLDWIDE SUPPORT

Flight Plan

To understand the support required from the tracking and telemetry stations around the world, a brief review of a typical Lunar Orbiter flight plan is in order. Precise timing, of course, varies with the launch day as well as with the launch time on a given day.

After launch, the vehicle rises vertically and turns a prescribed amount about its longitudinal (vertical) axis so that the desired azimuth is obtained when the pitch-over maneuver is started. After the Atlas booster engines are cut off and jettisoned, sustainer and vernier engines control vehicle position and velocity. Immediately following vernier engine cutoff, the nose fairing is jettisoned and Atlas-Agena separation occurs. After a pitch maneuver to the proper attitude, the Agena fires to inject the vehicle into a 100-mile parking orbit.

After coasting for a predetermined time in the Earth parking orbit, the Agena is fired a second time to place the vehicle in a translunar trajectory. This is followed by the separation of the spacecraft from the Agena and by an Agena retromaneuver to reduce the probability of its interfering with the spacecraft or hitting the Moon. A list of key events between launch and retromaneuver is given in table 18-III, and a schematic of the trajectory is shown in figure 18-14.

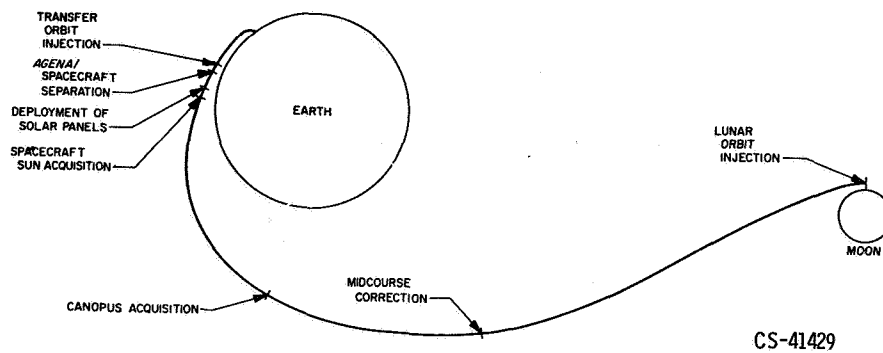


Figure 18-14. - Sequence of spacecraft flight events.

Ground Support

During the entire mission, the Atlas-Agena-Orbiter is in contact with the ground, both electronically and optically. Messages, consisting of commands to the vehicle and spacecraft and information to the ground, are constantly being exchanged. The facilities for this communication are distributed throughout the world; figure 18-15 shows the location primarily of the NASA ground-based communications activities, and table 18-IV lists the ETR facilities.

Telemetry. - Information generated or collected by the Orbiter or its vehicle is transmitted back to the ground stations near the ground track. At first, the information is received directly by Cape Kennedy, but later, other stations take over. The data are recorded on magnetic tape for immediate and later analysis.

Tracking. - Most of the installations that collect telemetry data are also involved in tracking; some stations are specifically designed for tracking only. Tracking can be either electronic or optical. Optical tracking is limited to the early stages of flight, so facilities for this are mostly near the launch area. Electronic tracking is not so limited and its distribution is world-wide.

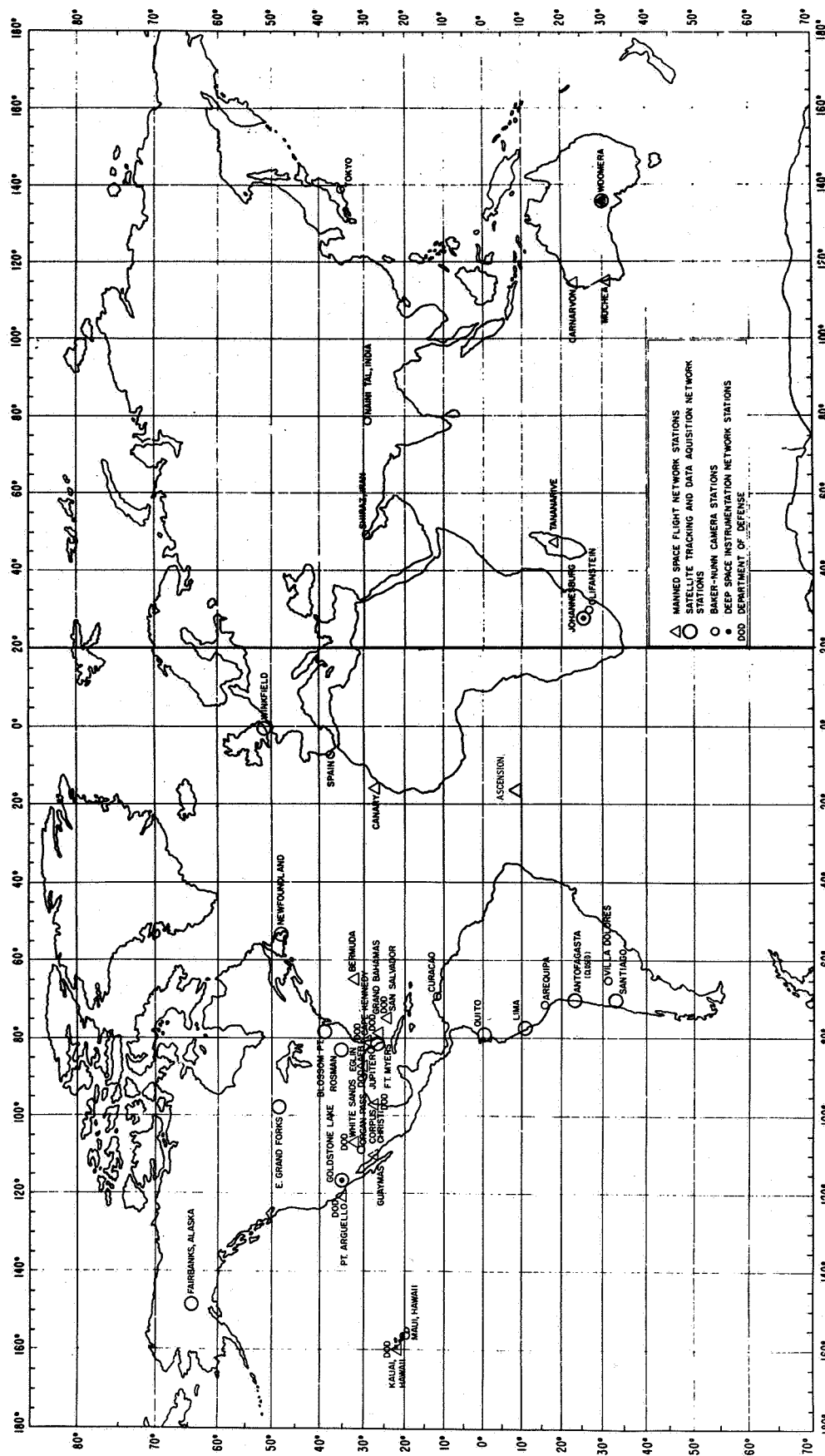


Figure 18-15. - Geodetic positions of NASA tracking facilities.

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TABLE 18-1. - FLIGHT PLANNING DOCUMENTS

Title	Publication date (a)	Description
Planning Estimate	L-24M	Describes general program and summarizes launch range support requirements. Must be approved before detailed range planning on program can be initiated.
Project Development Plan	L-24M	Describes the resources required for the Lunar Orbiter Program, including manpower estimates, program cost and funding, management organization. Delineates areas of responsibility among the NASA agencies and contractors.
Booster Requirements Document	L-18M	Combines into one document those launch vehicle system needs that are considered to be standard and not program-peculiar.
Program Requirements Document	L-12M	Defines those program needs that are levied on the launch support range by the user. Authorizes the range to take action to satisfy program needs.
Program Support Plan	L-10M ^b	Outlines the action to be taken by the launch range to satisfy program requirements and states whether the requirements can be met with existing resources or whether new facilities are needed.
Operations Requirement	(c)	Supplements the Program Requirements Document by describing in greater detail the final information, services, and related requirements for accomplishment of an individual test or test series within the overall program.
Operations Directive	(c)	Lists resources and methods to be used to support the test or test series.
Launch Operations Plan	L-9M, L-6M, L-3M, L-1M	Defines the flight objectives, system organization, space vehicle system configuration, operational range support facilities, data processing, launch constraints, and criteria requirements necessary to support program planning.
Flight Termination Systems Report	L-6M	Provides overall description of the space vehicle destruct system, including wiring diagrams and photographs, and a summary of test results showing system performance. This is the basic document for obtaining approval of the flight termination system for use on the range.

Range Safety Report	(d)	Provides trajectory data, dispersion data, and impact data resulting from malfunction or explosion during the ascent. Provides basic data for obtaining range approval for a flight on a particular launch azimuth. Describes the space vehicle pyrotechnics, propellants, and pneumatics and defines the control of these items during testing and installation operations at the launch pad. Tabulates selected events from each individual contractor countdown and defines the combined operations necessary to verify space vehicle flight readiness. Revises the Launch Operations Plan and lists the following final launch criteria:
Pad Safety Report	L-30D	1. Sequence of events
Countdown Manual	L-30D	2. Telemetry system instrumentation and landline changes
Launch Information Package	L-10D, L-5D	3. Propellant loading information
		4. Launch and hold limitations
		5. Final velocity meter settings
		6. Final weight statement
		7. Launch window
Firing Tables and Supplementary Range Documentation	L-6W	Contains launch-to-lunar-encounter trajectories, launch plan, and launch window information - presented on a time-lapsed basis from launch.
Spacecraft Handling Plan	L-5M	Describes the hazardous spacecraft systems, their operation, and handling procedures.
Booster Guidance Equations	L-6W	These equations are used for the real-time control of the Atlas to increase the accuracy obtainable from the auto-pilot and flight control system.
Mission Operations Plan	L-3M	Presents the overall authority and control of launch and flight operations for the mission. The document defines agencies and agency relations, operations, resources required, documentation, and schedule of implementation and operations.

^aBased on scheduled launch date where L-M, W, or D is launch date (L) minus x-number of months (M), weeks (W), or days (D).

^bDocument revised as required.

^cPublished 30 days before the particular test or test series.

^dFinal Trajectory Package portion of report published 6 weeks before scheduled launch date.

TABLE 18-II. - COUNTDOWN EVENTS

Time, EST	Count, min	Event
0941	T-460	Man countdown stations
0946	T-455	Start countdown
1009	T-432	Start preparations for spacecraft power turn-on
1011	T-430	Radiation clearance required
1041	T-400	Project Representative at Central Control console and check all communications lines with blockhouse
1046	T-395	Start spacecraft subsystem checks Agena ordnance delivered to pad
1056	T-385	Local radiofrequency silence until T-315 (spacecraft in low power mode) Start mechanical installation of vehicle pyrotechnics
1206	T-315	Range countdown starts Ordnance installation complete Radiofrequency silence released
1211	T-310	Start Agena telemetry and beacon checkout
1246	T-275	Range Safety Command Test
1306	T-255	Local radiofrequency silence until T-230 (spacecraft in low power mode) Start electrical hookup of pyrotechnics (Atlas and Agena)
1346	T-215	Spacecraft subsystems test complete Spacecraft programmer memory loading
1436	T-165	All personnel not involved in Agena tanking clear the pad area and retire to roadblock
1441	T-160	Pumphouse no. 4 manned and operational
1446	T-155	Start Agena fuel (UDMH) tanking
1451	T-150	Atlas telemetry warmup
1455	T-146	Guidance command test no. 1
1506	T-135	Agena fuel tanking complete Pad area clear for essential work Spacecraft programmer memory loading complete
1516	T-125	Remove service tower
1551	T-90	Start Agena oxidizer (IRFNA) tanking Agena beacon range calibration check
1616	T-65	Agena oxidizer tanking complete
1621	T-60	Built-in hold (50 min nominal) Clear all private vehicles and nonessential support vehicles from parking and pad areas
1711	T-60	Built-in hold ends Start spacecraft internal power checks
1720	T-51	Start guidance command test no. 2
1721	T-50	Spacecraft internal power checks complete
1736	T-35	Start liquid-oxygen tanking
1741	T-30	All systems verify that there are no outstanding problems Photo subsystem final preparations
1749	T-22	Start final Range Safety commitment
1804	T-7	Built-in 10-minute hold
1814	T-7	Built-in hold ends Agena switched to internal power
1816	T-5	Spacecraft switched to internal power
1818	T-3	Spacecraft programmer clock running
1819	T-2	Atlas switched to internal power
1821	T-0	Launch

TABLE 18-III. - SEQUENCE OF FLIGHT EVENTS

Event	Time	
	T+sec	min:sec
Liftoff	T+0	00:00
Start roll program	T+2	00:02
Start booster pitch program	T+15	00:15
Ground guidance commands to booster become effective	T+80	01:20
Booster engines cutoff	T+129.0	02:09.0
Jettison booster	T+132.1	02:12.1
Ground guidance commands to sustainer engine become effective	T+138.1	02:18.1
Start Agena restart timer ^a	T+250.7	04:10.7
Sustainer engine cutoff	T+287.2	04:47.2
Start Agena sequence timer ^a	T+290.6	04:50.6
Vernier engines cutoff	T+307.5	05:07.5
Jettison nose fairing	T+309.5	05:09.5
Atlas/Agena separation	T+311.5	05:11.5
Agena first-burn ignition ^a	T+364.5	06:04.5
Agena first-burn cutoff ^a	T+516.8	08:36.8
Agena second-burn ignition ^a	T+1315.0	21:55.0
Agena second-burn cutoff ^a	T+1401.5	23:21.5
Payload separation ^a	T+1567.7	26:07.7
Agena retromaneuver ^a	T+2167.7	36:07.7

^aTime of occurrence is variable.

TABLE 18-IV. - EASTERN TEST RANGE INSTRUMENTATION

Station	Instrumentation	Use
Cape Kennedy (Station 1)	Ballistic cameras Cinetheodolites Radar Fixed camera systems Pad cameras Telemetry receiving station Command destruct Wire sky screen Television sky screen	Metric data Metric data Range safety Metric data Engineering sequential Vehicle/spacecraft data Range safety Range safety Range safety
Patrick AFB (Station 0)	Cinetheodolites Radar Cameras	Metric data Range safety Engineering sequential
Melbourne Beach	Cameras	Engineering sequential
Vero Beach	Cameras	Engineering sequential
Grand Bahama Island (Station 3)	Radar Ballistic cameras Telemetry receiving station Command destruct	Metric data Metric data Vehicle/spacecraft data Range safety
Merritt Island (Station 19)	Radar	Metric data
Grand Turk (Station 7)	Command destruct Radar	Range safety Metric data
Antigua (Station 91)	Radar Telemetry receiving station Command destruct	Metric data, range safety Vehicle/spacecraft data Range safety
Ascension (Station 12)	Radar Telemetry receiving station	Metric data Vehicle/spacecraft data
Bermuda	Radar	Metric data
Pretoria (Station 13)	Radar Telemetry receiving station	Metric data Vehicle/spacecraft data
Ship	Radar Telemetry receiving station	Metric data Vehicle/spacecraft data
Aircraft	Telemetry data receiving equipment	Return of data